

SECRET

Declass Review by
NIMA/DOD

PAR 216

FINAL REPORT
Exposure of Photographic Material
with Lasers

15 January 1965

Prepared by:

[Redacted Signature Box]

25X1

[Redacted Content Box]

25X1

Copy 1 of 25

SECRET

SECRET

PAR 216

15 Jan 65

TABLE OF CONTENTS

| | <u>Page</u> |
|--|-------------|
| I SUMMARY | 1 |
| II SUBJECT | 2 |
| III TASK/PROBLEM | 2 |
| IV DISCUSSION | 2 |
| A. Exploratory Experiments | 2 |
| B. Refinement Experiments | 2 |
| C. Comparative Gamma Laser vs Filtered Tungsten Exposure | 6 |
| D. Effect of Coherence | 9 |
| V CONCLUSIONS | 13 |
| VI RECOMMENDATIONS | 16 |

SECRET

SECRET

PAR 216

15 Jan 65

LIST OF ILLUSTRATIONS

| <u>Figure</u> | | <u>Page</u> |
|---------------|--|-------------|
| 1 | Lab Setup for Laser Photo Study | 3 |
| 2 | Prints from Films Exposed on the Setup of Fig. 1 with [] 5200 Laser | 5 |
| 3 | Prints from Films Exposed on the Setup of Fig. 1 with the [] 130 Laser | 7 |
| 4 | The Surface Plate Mounted, [] Optical System for Optical Projection Studies | 11 |
| 5 | Optical Schematic of the System of Fig. 4 (Mirrors are not indicated here) | 12 |
| 6 | Projected Image of Reticle Pattern with Increas- ing Amounts of Defocusing. (Tungsten Source) | 14 |
| 7 | Projected Image of Reticle Pattern with Increas- ing Amounts of Defocusing. (HeNe Laser Source) | 15 |

25X1

SECRET

SECRET

PAR 216

15 Jan 65

SUMMARY

No experimental evidence or theoretical prediction was found that a photographic emulsion (acting as a detector) reacts any differently to coherent than to non-coherent radiation, provided they are of the same approximate wavelength and energy level.

Photographic materials for the detection of laser generated radiation may be chosen by the same criteria as for the detection of other radiation of the same wavelength and energy level.

SECRET

SECRET

PAR 216

15 Jan 65

SUBJECT: Exposure of Photographic Material with Lasers

TASK/PROBLEM

1. Determine the manner and degree of the interaction of present and predictable future photographic films with coherent radiation from laser sources in red and near IR spectrum ranges.

DISCUSSION

2. The starting point of our study was the new helium-neon gas laser source offered in commercial form by two manufacturers,

a. [REDACTED] Model 5200.

b. [REDACTED] Model 130.

The output from these units is at 6328A. Panchromatic films with extended red response have good relative sensitivity at this wavelength. A single film of this type was chosen for the start of the experiments to reduce the number of variables in the exploratory experiments. The film used was Kodak Type 8401 Plus-X-Aerecon.

3. Exploratory Experiments:

a. The exploratory experiments were begun with a laboratory setup (shown in Fig. 1) consisting of the following:

- (1) Commercial laser with a housing unit.
- (2) Variety of optical elements for beam control.
- (3) Film holder.

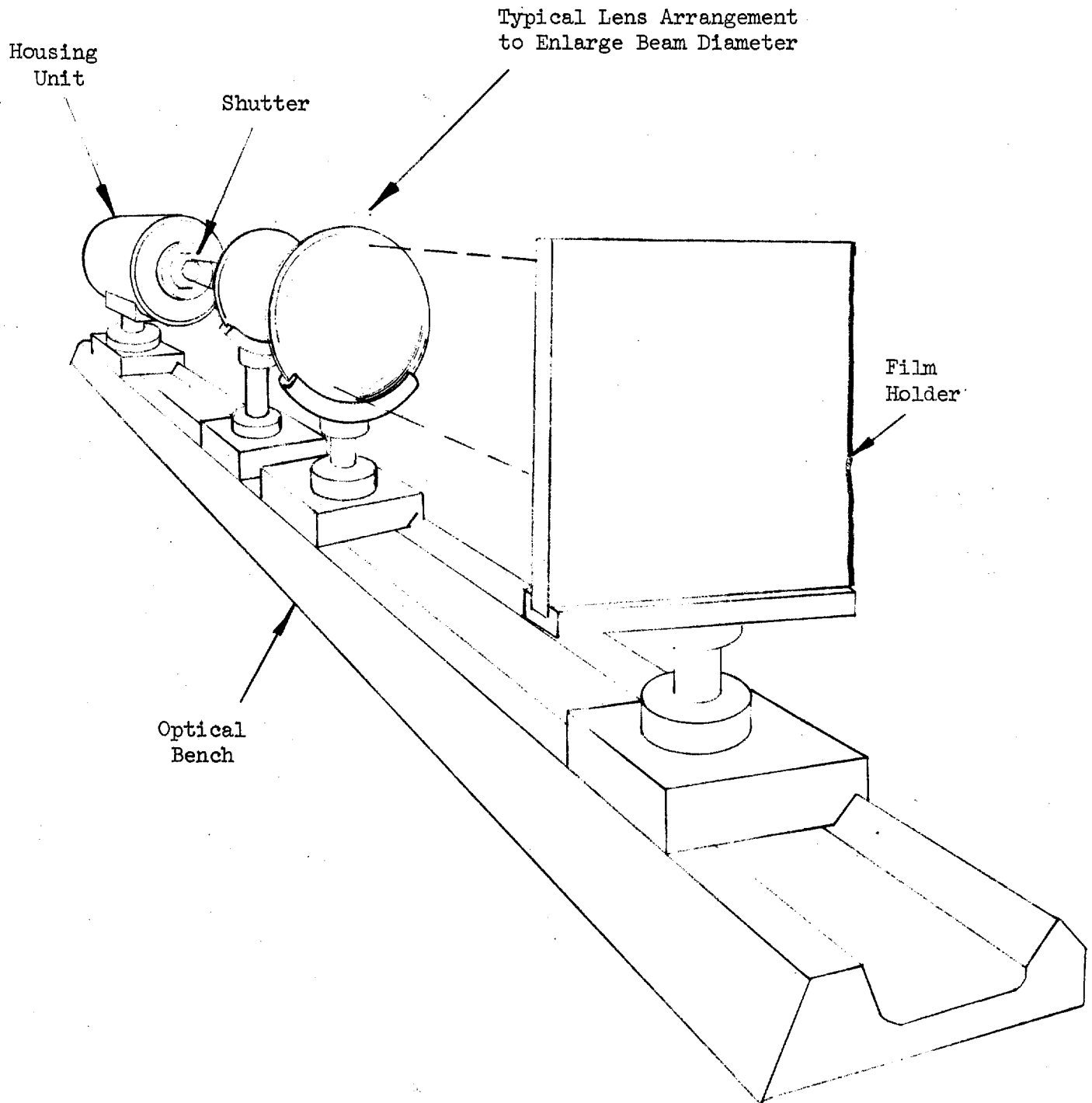
b. The housing unit is a wooden box which both baffles the laser pump energy and provides a fixed mount for the Kodak Synchro-rapid 800 Shutter. For exposure reference, this unit can also house a small 6 volt, 40 watt standard tungsten filament source.

SECRET

SECRET

PAR 216

15 Jan 65



LAD SET UP FOR LASER PHOTO STUDY

SECRET

SECRET

PAR 216

15 Jan 65

c. The optical components in the setup are single element positive lenses and are used to vary beam size and divergence. The film holder is simply the rear section of a 4 x 5 Kodak Master View Camera modified to accept 70mm film.

d. The first exposures obtained with this equipment were of the direct unmodified beam from the [] 5200, on 8401 Plus-X-Aerecon Film. Fig. 2a shows this beam exposed at 1/800 second and with the exception of the extreme peripheral region, no structure is apparent. Fig. 2b shows the same beam enlarged with a single lens element. In this print, much of the interference pattern created with the laser unit can be seen. Fig. 2c shows the fine structure in these interference rings at increased magnification.

25X1

4. Refinement of Experiments:

a. To demonstrate that these interference phenomena were not characteristic of the [] 5200 alone, the [] laser beam was photographed using Type 8401 panchromatic film. Fig. 3a and Fig. 3b are representative of those taken. Fig. 3a shows the beam with magnification comparable to that in Fig. 2b and although the two are not alike, they both display the strong interference patterns.

25X1

b. Fig. 3b, in addition to displaying this beam under higher magnification, shows the effect of foreign particles in the beam path. The elongated dark region in the center and the dark circular pattern on the left-hand edge were created by a "dot and dash" dig on the lens surface. The lower contrast circular patterns throughout the print are due to dust particles, most of which are also on the lens surface. Subsequent experimentation indicated the clarity or sharpness of these foreign particle patterns was independent of both the surface they were on and their location in the beam.

SECRET

PAR 216
15 Jan 65

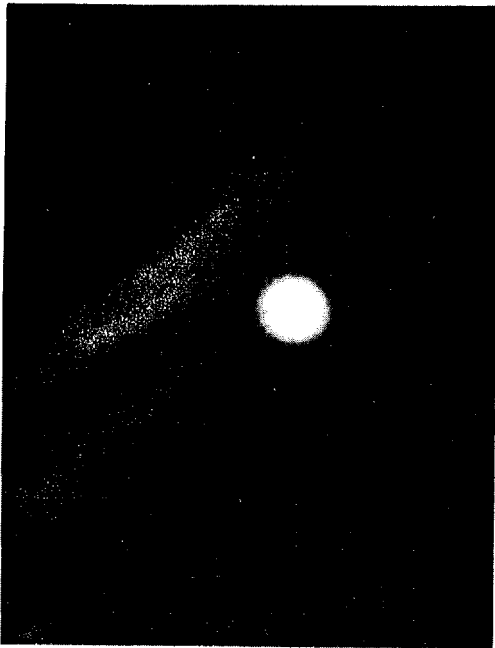


Figure 2a. No beam enlargement

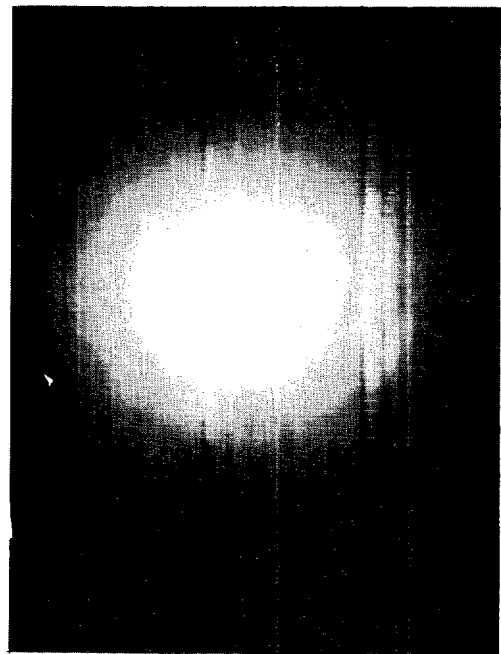


Figure 2b. Beam enlarged with a single lens element

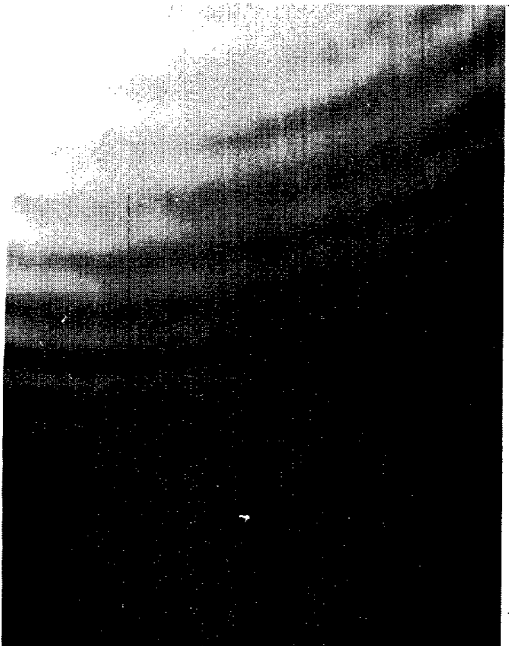


Figure 2c. Fine structure at edge of beam - high magnification

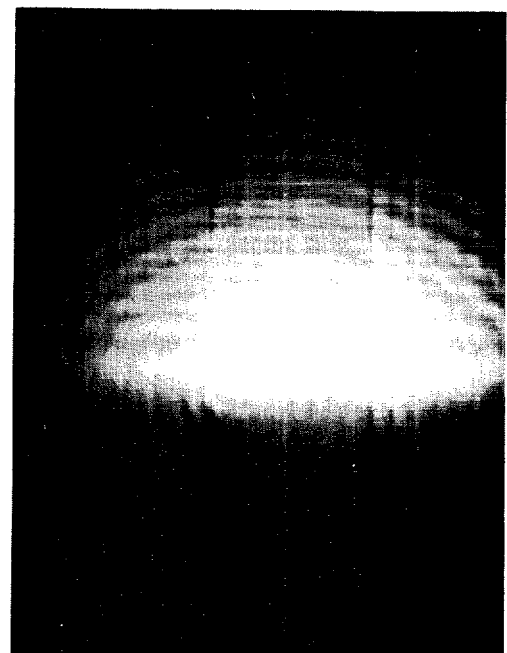


Figure 2d. Interference patterns with a "knife edge" in the beam

Figure 2. Prints from Films Exposed on the Setup of Figure 1 with 5200 Laser

25X1

SECRET

PAR 216

15 Jan 65

c. After these various interference patterns had been examined, effort was directed toward obtaining a uniform field with the laser beam. The first approach was to greatly magnify the beam, scan it for a reasonably uniform region, and photograph it. Fig. 3c shows the type of pattern created by this technique and Fig. 3d shows the result of using this beam to expose a step tablet.

d. In a second approach, ground glass was inserted in the beam and an exposure made of the resultant diffuse radiation. This technique showed improved uniformity, but the exposures were still not comparable to those made with a tungsten filament source. In quantitatively evaluating this uniformity, a complete series of ten exposures was made ranging from 1/800 second to one second for several beam magnifications. The density variation in the central portion of the individual exposures due to non-uniformity of the beam was about 5 percent (gamma value approximately 0.5).

e. In an experiment to compare the effects of laser vs filtered tungsten exposure upon contrast, one piece of film was exposed with the Model 101 Sensitometer (red filtered tungsten light) and a second piece was exposed with the divergent laser beam through a calibrated step tablet placed in contact with the film. By developing both pieces of film together and measuring their densities with a Type 31A Densitometer, comparative gamma values were obtained as shown in Table 1.

SECRET

SECRET

PAR 216

15 Jan 65

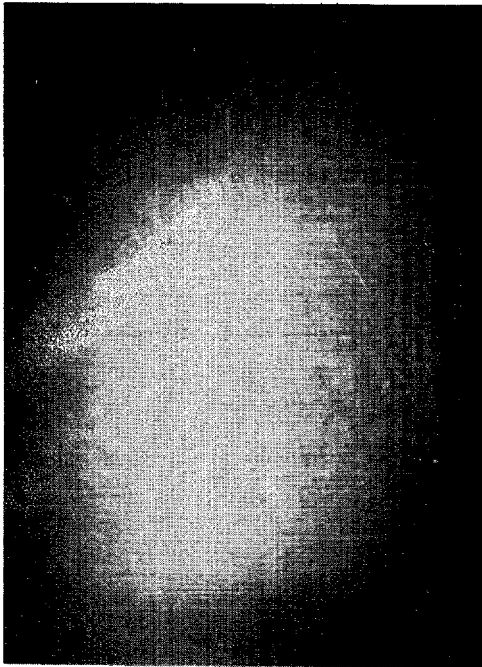


Figure 3a. Exposure at approximate conditions of Figure 2b



Figure 3b. Higher magnification (greater beam divergence) than Figure 3a, and showing effect of foreign objects in beam path

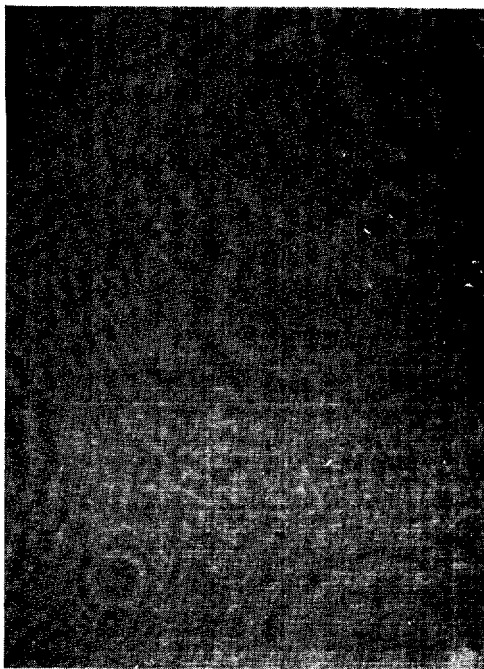


Figure 3c. Section of greatly magnified beam selected for best uniformity

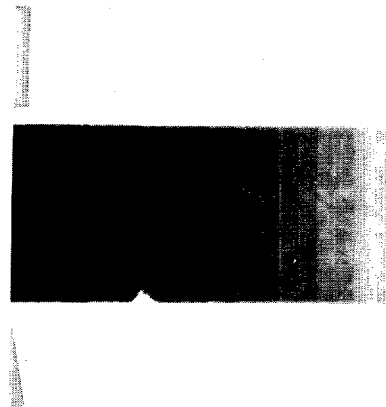


Figure 3d. Step tablet exposure in a portion of beam shown in Figure 3c

Figure 3. Prints from Films Exposed on the Setup of

Approved For Release 2003/01/28 : CIA-RDP78B04770A002600010001-3

Excluded from automatic downgrading and declassification

SECRET

SECRET

PAR 216

15 Jan 65

TABLE 1

Comparative Gamma Laser vs Filtered Tungsten Exposure

| Receptor Film | 8401 Plus-X-Aerecon Developed in D-19 | | | | 8401 Plus-X-Aerecon Developed in D-76 | | | |
|---|--|------|------|------|--|------|------|------|
| Test Series | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Gamma with Red Filtered Tungsten Source | 1.12 | 1.17 | 1.06 | 1.02 | .99 | 1.00 | .76 | .92 |
| Gamma with Laser (6328A) Source | 1.12 | 1.04 | 1.10 | 1.04 | .98 | 1.07 | .89 | .88 |
| Gamma Difference (Laser - Tungsten) | .00 | -.13 | +.04 | +.02 | -.01 | +.07 | +.12 | -.04 |

SECRET

SECRET

PAR 216

15 Jan 65

Considerable variability in the gamma values obtained for laser exposure was caused by lack of laser beam uniformity. Within the experimental error, it was concluded that no difference exists in the gamma obtained with laser exposure versus that obtained with a noncoherent source of the same approximate wavelength.

5. Effect of Coherence:

a. It was obvious that if the laser were to be useful in exposing photographs of any type, in addition to our need for the purposes of this study program, the beam uniformity must be improved. The use of ground glass, as described above, was suspected of destroying coherence. At this point, arrangements were made with our consultant optical physicist to discuss methods for measuring coherence. The discussion did not suggest any rapid convenient methods for measurement of coherence except to observe the presence or absence of interference and diffraction effects.

b. During this discussion, we did arrive at a fuller understanding of the nature of coherence. This understanding produced the conclusion that much work has been done with coherent light and that we have data to answer most of the questions posed for this study. Studies on coherent light date back to Fresnel, Fraunhofer, Airy, etc., in the Nineteenth Century, and photographic materials have been used since their invention to record the diffraction effects related to it. The new factor generated by laser source is that coherent radiation is now available at energy levels several orders of magnitude higher than before, and the coherence is more perfect. Photographic exposures, which previously required minutes to hours, can now be made in seconds or fractional seconds.

c. In the various experiments described above, we can find no evidence that the photographic emulsion (acting as a detector) reacts any differently to coherent radiation than to noncoherent light of about the same wavelength and energy level. Discussion of this probable effect

SECRET

SECRET

PAR 216

15 Jan 65

of coherence upon latent image formation with the head of the Physics Department of the Contractor's Research Laboratories has provided theoretical confirmation of that observation.

d. The interference effects observed in photographic exposures to laser (or other coherent radiation) can be explained as interference occurring outside the receiving photographic emulsion. With this conclusion, it was decided to terminate our studies on the photographic materials as a receiver of laser generated radiation.

6. In preparation for studies of the behaviour of photographic materials as the object in optical projection with a laser source, a preliminary reticle projection study was initiated to compare tungsten versus laser sources in an optical projection system. The laboratory setup for this study consisted essentially of a single element lens which projected the .005-inch and 0.1-millimeter scales of a measuring magnifier onto a 4 x 5-inch sheet of SO-243 film. Exposures were made by positioning the film plane at the geometrical focus of the projection lens and at several positions both ahead of and behind it.

25X1

7. A system with high-quality doublet objectives and mounted on a rigid, shock-mounted surface plate was assembled to perform the optical projection studies on a more quantitative basis. This system is shown in Fig. 4. The elements of the system are mounted in aluminum blocks and are located in one of two hardwood vee-troughs which lie parallel to the optical path. A schematic view of the optical system without the two mirrors is shown in Fig. 5.

8. Before the experimental work was started with this new projector, we were visited by a customer representative. Our proposed effort in studying spatial filtering and performance of photographic films as the object in a laser illuminated projection system was quite similar to work already well advanced under the customer's sponsorship in another laboratory.

SECRET

Approved For Release 2003/01/28 : CIA-RDP78B04770A002600010001-3

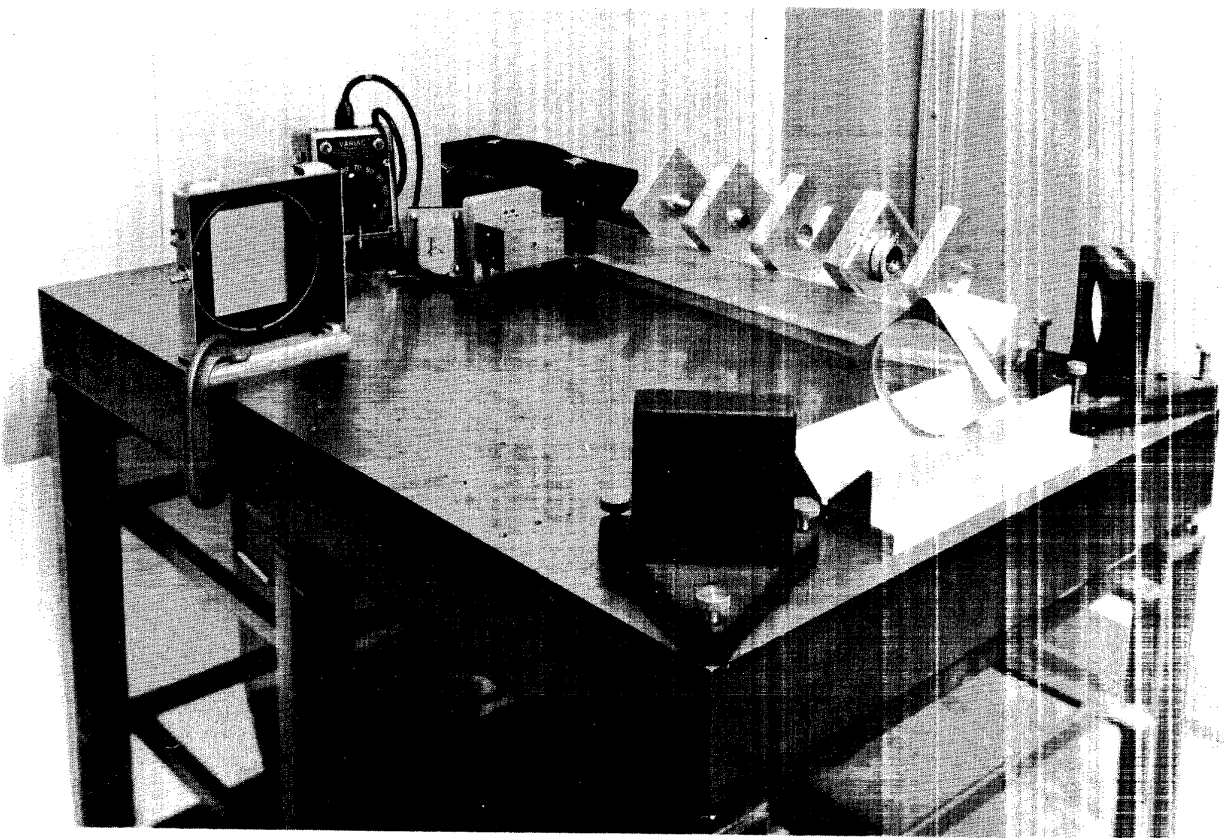


Figure 4 The Surface Platen Mounted,
Optical System for Optical Projection Studies
Approved For Release 2003/01/28 : CIA-RDP78B04770A002600010001-3

SECRET

TOP SECRET

25X1

GROUP 1
Excluded from automatic downgrading
and declassification

-11-

SECRET

PAR 216
15 Jan 65

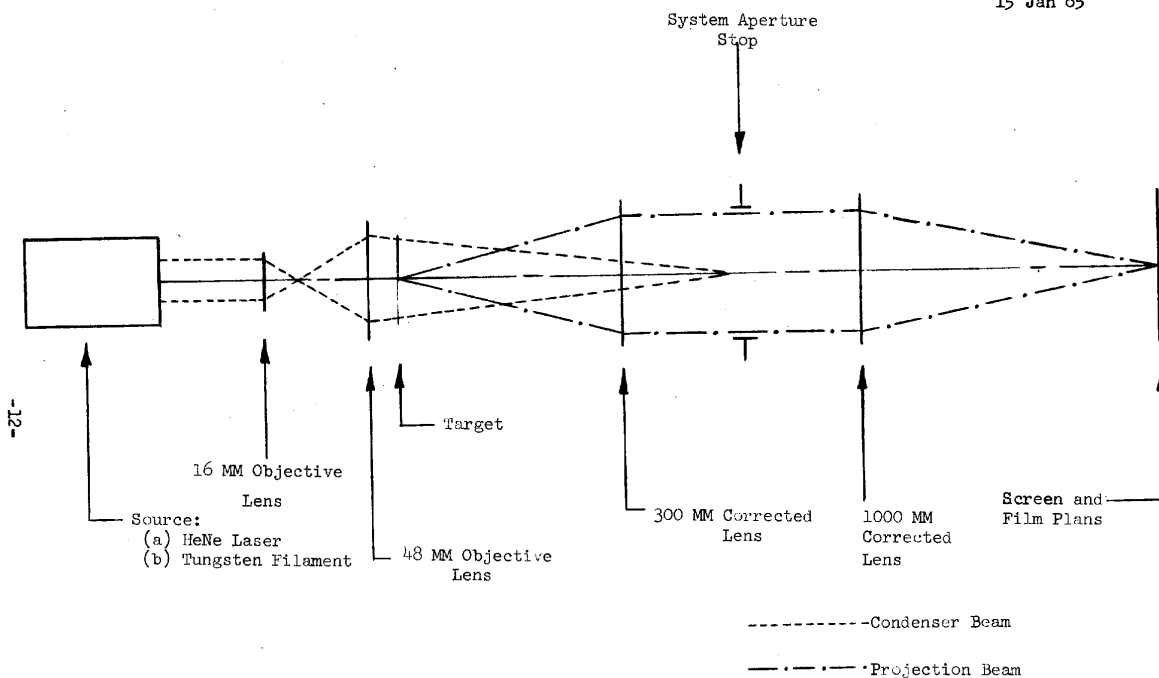


Figure 5. Optical Schematic of the System of Fig. 4
(Mirrors are not indicated here)

SECRET

GROUP 1
Excluded from automatic downgrading and declassification

SECRET

SECRET

PAR 216

15 Jan 65

We were instructed to complete our effort to duplicate the examples shown in Quarterly Report No. 1 for FY-65 with the diffraction limited projector and to terminate the laboratory work.

9. The experiment that was completed involved projecting a [] magnifier reticle with the reticle located at the optimum focal position and several positions beyond focus. Fig. 6 shows the results of these projections with the tungsten filament source as the illuminator. Fig. 6a shows the projected image with the reticle in focus. Fig. 6b, 6c, and 6d show successive images of the reticle as it is moved nearer the film plane in quarter-inch increments. It is apparent that recognition is almost completely lost for a reticle shift in excess of one-quarter inch. The degradation, however, is very similar to that obtained with the initial projection system.

10. Fig. 7 shows an identical sequence of exposures using the [] HeNe gas laser as the illuminator. Constructive reinforcement of the reticle lines is quite pronounced providing the effect of image formation at extreme amounts of defocusing. The interference patterns arising from dust on various glass-air surfaces in the optical system would make such an image useful only under special conditions.

CONCLUSIONS

11. The energy level of the HeNe laser is such that the beam when expanded to approximately five inches in diameter will expose Kodak Type 8401 Plus-X-Aerecon Film to a flash density over 1.0 with .010 second exposure.

12. The beam delivered by the laser is not uniform in radiance across the aperture, producing a mottled effect in flash exposures. The pattern varies with the end mirrors of the laser and appears to be partially due to imperfections in the mirrors. Work on PAR 217 indicates that there are other factors also.

SECRET

SECRET

15 JAN 75

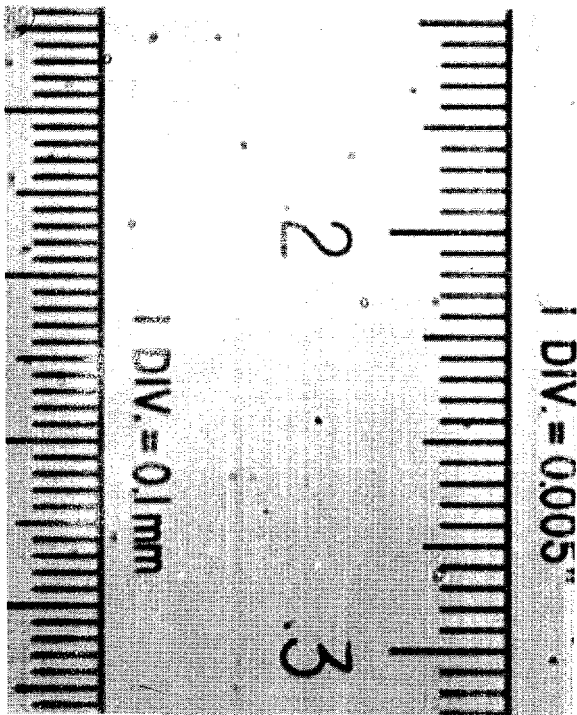


Figure 6a

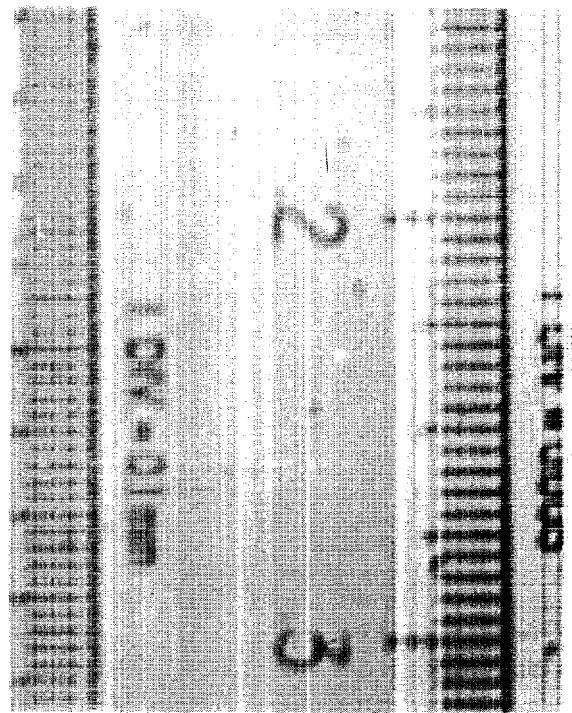


Figure 6b

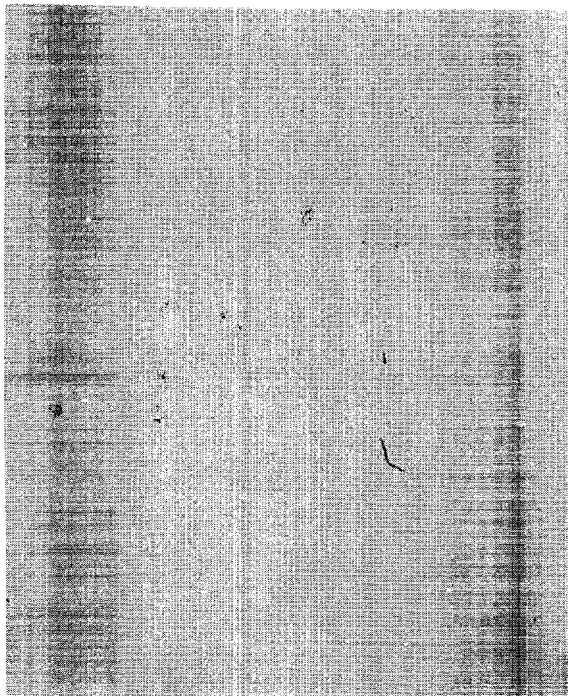


Figure 6c

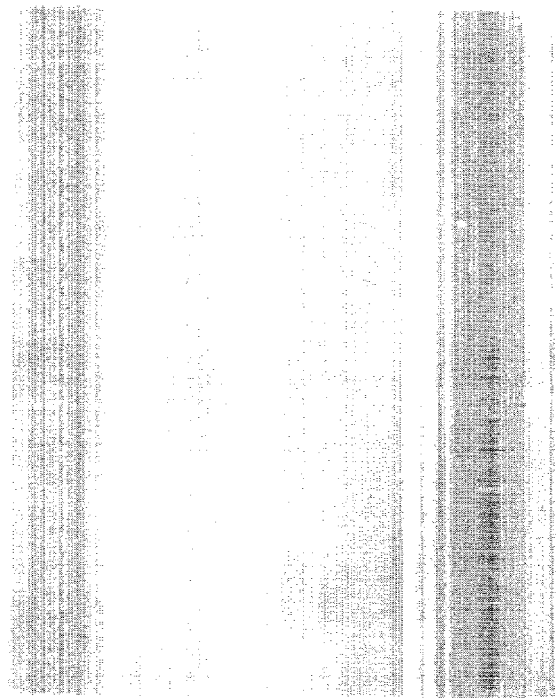


Figure 6d

Figure 6 Projected Image of Reticle Pattern with Increasing Amounts of De-Focusing (Tungsten Source)

SECRET

SECRET

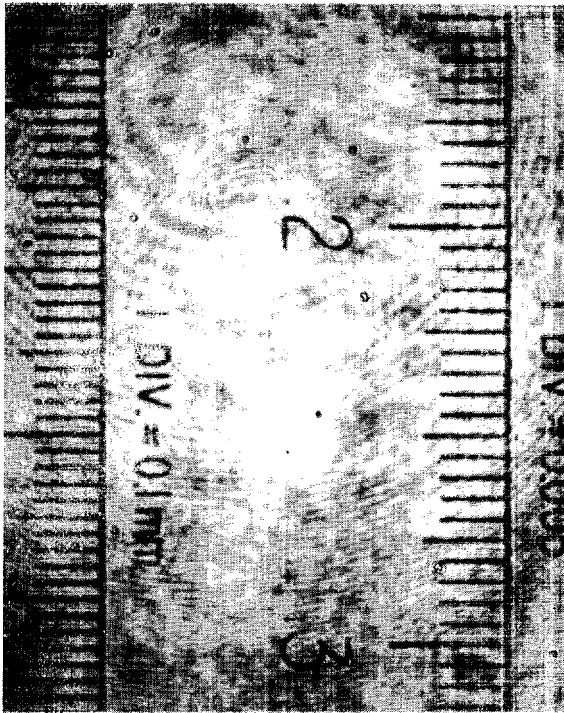


Figure 7a

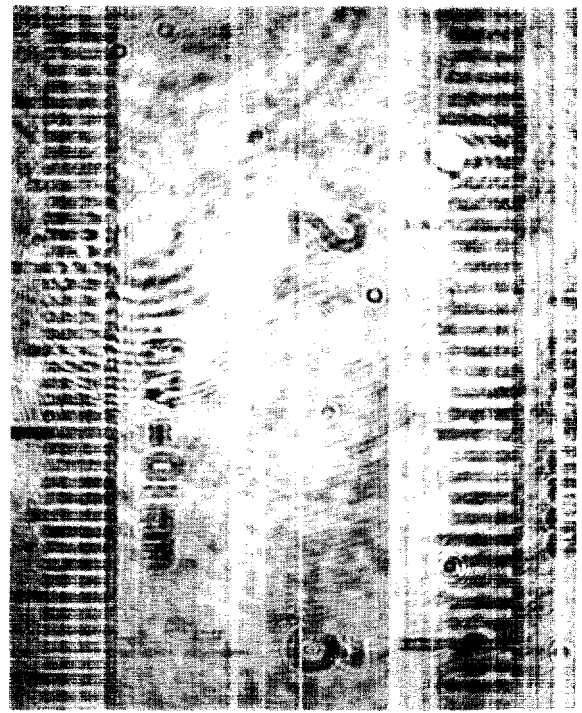


Figure 7b

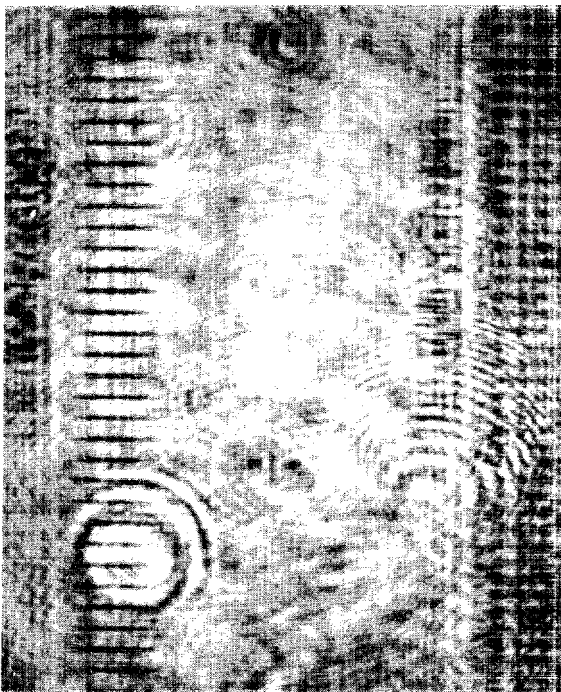


Figure 7c

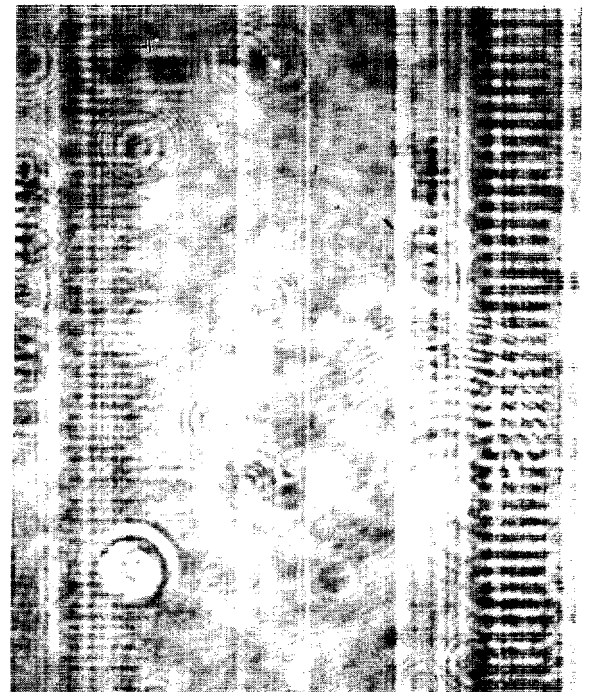


Figure 7d

Figure 7 Projected Image of Reticle Pattern with Increasing Amounts of De-Focusing (HeNe Laser Source)

SECRET

SECRET

PAR 216

15 Jan 65

13. Our efforts to provide a "coherence meter" produced only the observation that "if the light is coherent there will be interference fringes".

14. The use of fully coherent light in a photographic system will generate gross problems with diffraction patterns from dust and scratches anywhere in the beam and should be considered only when special benefits are provided by its use.

15. No technique was developed in this project to improve beam uniformity of the laser. A published paper by H. Heckscher and B. J. Thompson⁽¹⁾, which came to our attention after completion of the experimental effort in this project, may offer a possible method.

16. We can find no experimental evidence or theoretical prediction that a photographic emulsion (acting as a detector) reacts any differently to coherent than to noncoherent radiation, provided they are of the same approximate wavelength and energy level.

RECOMMENDATIONS

17. Photographic materials for detection of laser generated radiation may be chosen by the same criteria as for detection of noncoherent radiation of the same wavelength and energy level. The occasional problems of unwanted interference effects as related to the film structure should be examined for the particular situation when encountered.

(1) Heckscher and Thompson, Photographic Science Engineering, 8:260 (1964)

SECRET